Consumer acceptability of blueberry confections formulated with blueberry extract and lyophilized whole blueberry powder

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Abstract

Functional food products (FFP) have been shown to enhance overall health and aid in disease prevention. FFP's, aside from delivering the intended health benefit, need to be sensory acceptable so that they are regularly consumed. Confections make excellent FFPs and delivery vehicles for bioactives due to their high consumer compliance, and their ability to deliver a consistent composition of phytochemicals even after processing and storage. Blueberries contain polyphenols, primarily anthocyanins, which have been shown to have anti-inflammatory properties and other health benefits. However, most of the pre-clinical evidence regarding the health benefits of blueberries have been seen using a phytochemical-rich blueberry extract, not the whole fruit. When assessing possible blueberry sources in a functional confection, whole lyophilized blueberry powder was selected, delivering equivalent phytochemical profiles without the chemical off-flavors attributed to the extract. It was hypothesized that confections made with lyophilized whole blueberry powder would be preferred to the confections made with blueberry extract. Therefore, the objective of this study was to conduct a sensory analysis of the two confections, including a paired preference test and an acceptability test using a 9-point hedonic scale rating overall liking, aroma, fruit flavor, bitterness, graininess, texture, and sweetness (n=75), with a significance level of α=0.05. Results of the preference test showed no significant preference among the two blueberry confections, with 43 individuals preferring the whole blueberry powder confection and 32 individuals preferring the blueberry extract confection. No significant differences were seen among hedonic scores except in graininess (p= 0.015) and average overall liking scores of both confections fell in the "like slightly" category (powder= 6.33, extract= 6.21). In conclusion, both the extract and powder confections were sensory acceptable for use in future clinical trials, but more work needs to be done comparing shelf stability and phytochemical uptake in humans.

Acknowledgements

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Curriculum Vitae

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Introduction

Functional food products (FFP) are defined as food products that are fortified or enriched to offer additional health benefits beyond a traditional healthy diet (Hasler 2002). These products have taken various forms throughout the industry, ranging from sports nutrition beverages to infant formula; however, one promising industry segment still in the development stages of functional food research is functional confectionary(Gibson and Williams 2001). Functional confectionary dates back to ancient times, with the creation of products that were designed to cure common ailments such as coughs or sore throats (Gibson and Williams 2001). Today, functional confections have evolved and can be formulated with various ingredients to fulfill specific physiological functions and provide numerous potential health benefits, extending well beyond the common cold (Gibson and Williams 2001). In the Vodovotz laboratory, it has been demonstrated in numerous clinical trials that confections make excellent FFPs and delivery vehicles for bioactives due to their high consumer compliance, and their ability to deliver a consistent composition of phytochemicals even after processing and storage (Gu et al. 2015).

Berries such as blackberries, strawberries, and blueberries are rich in bioactive compounds called anthocyanins, which are known chemopreventive agents(Stoner 2009). Previous studies have shown that anthocyanins may participate in the inhibition of chronic inflammatory processes commonly associated with the initiation and promotion of cancer in the body(Gu et al. 2014). While epidemiological evidence associates eating fresh blueberries with increased health, most of the pre-clinical evidence regarding the health benefits of blueberries have been seen using a phytochemical-rich blueberry extract and not the whole fruit. There are pros and cons to incorporating a whole fruit versus an extract in a functional confection delivery matrix. While there is ample literature evidence linking blueberry extract consumption with health benefits, whole freeze-dried blueberry powder has an ability to act at multiple stages in the

carcinogenesis process, reduce incidence of toxicities, and has can deliver complex phytochemical profiles that act synergistically without the chemical off-flavors attributed to the extract (Stoner 2009). When formulating functional foods for future clinical trials, consumer acceptance is of high importance to researchers in order to elicit high levels of compliance throughout a study. However, even though the debate between whole food versus extract inclusions in functional foods remains, a direct comparison of consumer acceptance of two equivalent functional food products, one with a whole food and one with a phytochemical rich extract has yet to be formally studied.

Problem Identification and Justification

In addition to many other adverse health effects, patients undergoing chemotherapy often experience significant cognitive decline, colloquially known in the medical community as "chemo brain"(Schagen et al. 1999). Around 78% of cancer patients who received chemotherapy as a treatment experience some level of chemo brain symptoms, and children and adolescents receiving such treatment are of special concern since deficits in memory and attention can affect their ability to learn later in life (Hudson et al. 2013). Currently no formal treatment exists to combat this side effect of chemotherapy, and often times, cancer patients with weakened immune systems and chronic exposure to toxic chemicals, are hesitant to add another pill, drug, or supplement to their treatment plan (Gu et al. 2014). However, a functional food solution like a blueberry confection can be a less intimidating option to help maintain or improve their mental acuity past their treatment of cancer and act as an adjuvant therapy in addition to traditional cancer treatment plans.

The rationale of this study was to determine which functional blueberry confection formulation had the highest consumer compliance and sensory acceptability- the blueberry extract formulation or the whole blueberry powder formulation. Blueberries were chosen as the

bioactive component of these confections because of their rich anthocyanin content, shown in other studies to improve both cognitive and overall health. The collected data was analyzed to determine if a significant preference existed between the two blueberry confection formulations and optimize various sensory attributes, in order to adjust current formulations and their increase consumer acceptance for use in future clinical trials. It was hypothesized that the confections made with the lyophilized whole blueberry powder would be more sensory acceptable- and, therefore, merit a greater consumer preference- than the confections made with the blueberry extract. The following objective was used to test the hypothesis:

Objective

The following objective will be met by analyzing the data obtained from a sensory analysis, sampling 75 adults at the Ohio State University consuming two different blueberry confections, one made with an extract and one made with a whole blueberry powder. An acceptability test, a paired-preference test, and a "Just About Right" test will make up the sensory methodology used to test this objective.

1. Investigate the sensory acceptability and determine consumer preference of two blueberry confections made with blueberry extract and lyophilized whole blueberry powder, and identify product parameters that need to be optimized.

Materials and Methods

Confection manufacturing

Confections were prepared according to the directions, flow diagram, and formulations listed below (Figure 1).

Ingredient	Blueberry Extract Confection (%)	Blueberry Powder Confection (%)
Water	37.0	37.0
Sugar	29.3	2.0
Jello Berry Blue	26.0	26.0
Knox Gelatin	4.5	4.5
Citric Acid	0.5	0.5
Blueberry Extract	2.8	0.0
Blueberry Powder	0.0	30.0
Total	100.0	100.0

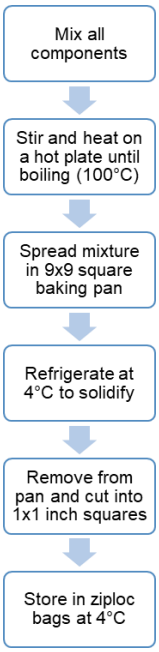

Figure 1. Blueberry confection formulations and confection manufacturing flow diagram

The whole blueberry powder (N1112 Blueberry Powder) and blueberry extract (N1077 VitaBlue) used as inclusions in the gelatin confections were made from the same raw materials (Vaccinium corymbosum) and purchased from the same supplier (Futureceuticals, Momence, IL). Both confections were prepared by mixing gelatin (Knox Gelatin, Treehouse Foods, Inc., Oakbrook, IL), sugar (Domino Foods Inc., Iselin, NJ), citric acid (Tate and Lyle, Decatur, IL), Jell-O Berry Blue (Kraft Foods, Northfield, IL), and either the blueberry extract or powder described previously. This mixture was then stirred and heated on a hot-plate until reaching 100°C, which typically took approximately 20 minutes. Upon reaching boiling, the confection base was removed from heat and moved to a 9X9 in square baking pan lined with parchment paper and moved into a refrigerator (4 °C) to solidify, which took approximately 3 hours. Confections were then removed from the pan and cut into squares (1in x1in x1.5 in), placed in Ziploc bags, and stored at 4 °C, avoiding air and light, to mimic how the confections would be stored if used in a clinical trial. The final formulation the blueberry extract and blueberry powder confections can be seen below in Table 1. Both confections were formulated to deliver

approximately 320 mg of anthocyanins/ 100 g dose (the extract was found to be ten times as concentrated as the whole food powder with regards to anthocyanin content), or about five confections, which is equivalent to eating 2 cups of fresh blueberries25.

Sensory analysis of blueberry confections

A sensory analysis (OSUIRB#2017E0569) was conducted to explore likability and palatability of blueberry confections made with blueberry extract and whole blueberry powder. There were 75 individuals sampled in each test with results taken at a significance level of $\alpha=0.05$. Panelist demographics were compiled in Table 1.

Table 1. Panelist Demographics (n=75)

Gender		Age		Ethnicity	
Male	29	18-25	47	American Indian	0
		26-35	14	Asian/Island Pacific	7
		36-45	5	Black	3
Female	46	46-55	6	Hispanic	4
		56-65	3	White	61
		Over 65	0	Other	0

All three sensory tests were conducted at ambient temperature in sensory booths under standard fluorescent lighting. Panelists were provided water and saltine crackers and advised to rinse between each sample to prevent carry-over flavor contamination. Each sample was labeled with randomized 3-digit numbers and presented using a serial monadic scheme. Participants were familiarized with Compusense (Compusense Inc., Canada), the sensory acquisition software used to collect data during this study, and reminded to check the sample numbers they received against the number choices provided on the screen.

The panelists were then taken through an acceptability test, a paired preference test, and a "Just About Right" (JAR) test. The acceptability test used a 9-point Hedonic scale (1=Dislike Extremely to 9=Like Extremely) to rate overall liking, overall aroma, fruit flavor, bitterness, graininess, texture, and sweetness, represented by the ballot seen in Figure 2.

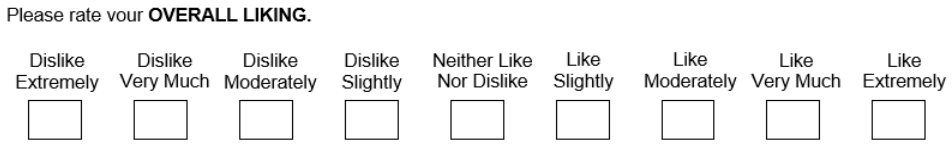

Figure 2. 9-pt Hedonic Scale Acceptability Test Ballot

The following ballot (Figure 3) was used in the paired-preference test:

Taste the two coded samples in the following order: _____ _____

Which of these two samples do you prefer?

Figure 3. Paired-Preference Test Ballot

Finally, The JAR test evaluated fruit aroma, stickiness, firmness, sweet flavor, sour flavor, bitter flavor and fruit flavor (1=Much Too Little to 5=Much Too Much), as shown by the ballot below (Figure 4).

Figure 4. "Just About Right" (JAR) Test Ballot

Data Analysis

Results from the sensory evaluation were collected using a computer software (Compusense, Ontario, CA). The acceptance data was assessed using a paired comparison t-test on SPSS software, the preference data was evaluated for significance using statistical binomial tables, and the JAR data was displayed in histograms by attribute and then assessed as JAR if greater than 70% of participants rated it as such.

Results and Discussion

Acceptability data was analyzed based on average hedonic liking scores for the outlined attributes and displayed in Figure 1.

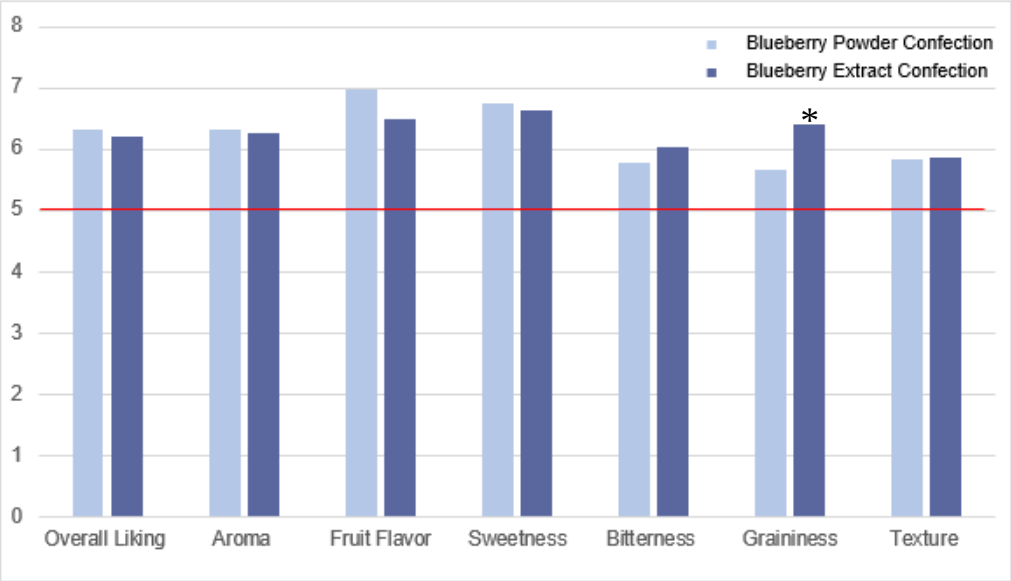

Figure 5. Average hedonic liking scores of selected attributes for two different confection formulations

All attributes tested were liked in some capacity, as indicated by the average hedonic liking scores reaching above the red-line which signified a score of 5 or "Neither like nor Dislike." Surprisingly, the differences in liking scores between formulations was minimal, and the only significant difference was seen in the level of graininess, which was not surprising considering the complexity and amount of fiber in the whole blueberry powder (Stoner 2009). This result indicated that panelists thought that the level of graininess seen in the blueberry extract confection was more acceptable than the level of graininess seen in the blueberry powder confection, most likely because the extract formulation was less grainy overall. This lack of significant difference among formulations was carried through to the preference test results (Table 3).

Table 3. Preference data analyzed for statistical significance by use of binomial tables

	# of responses collected from sensory analysis	# of responses needed for statistical significance
Powder Confection	43	47
Extract Confection	32	47

Since 75 individuals were sampled in this sensory evaluation, 47 correct responses were required in order to claim a significant preference between confection formulations, calculated using equation 1 below.

$$x= (z\sqrt{n}+n+1)/2; \text{ where } z=1.96 \text{ and } n=75 \quad (1)$$

Neither formulation received 47 responses; however, the powder formulation came close with 43 respondents saying that was the confection they preferred.

Finally, JAR data was analyzed to provide insight into how the outlined attributes could be optimized going forward. Attributes were considered satisfactory if 70% or more of participants responded that the given attribute was “just about right.” The results were compiled in Table 4, showing that only bitter flavor was satisfactory in the extract formulation, whereas fruit aroma and bitter flavor were satisfactory (>70%) in the powder formulation, with sweet flavor and fruit flavor close behind at 69.3%. Attributes that were not considered JAR for either formulation included stickiness, firmness, and sour flavor, and would need to be optimized before moving forward into clinical trials. This was done by constructing histograms for each non-JAR attribute and conducting a penalty analysis, with the end goal of satisfying the largest population of consumers and isolating the least number of consumers.

Table 4. JAR scores by attribute for each confection formulation

Attribute	Blueberry Extract Confection (%)	Blueberry Powder Confection (%)
Fruit Aroma	61.3	76.0
Stickiness	58.7	68.0
Firmness	45.3	62.7
Sweet Flavor	69.3	69.3
Sour Flavor	50.7	64.0
Bitter Flavor	85.3	78.7
Fruit Flavor	61.3	69.3

Sample histograms for the non-JAR attributes listed above were displayed in Figures 2A-4B.

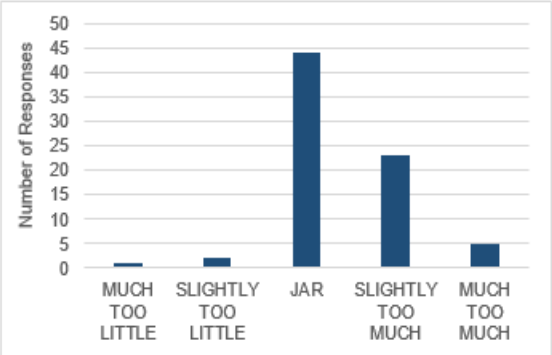

Figure 2A. JAR score for stickiness in blueberry extract confection

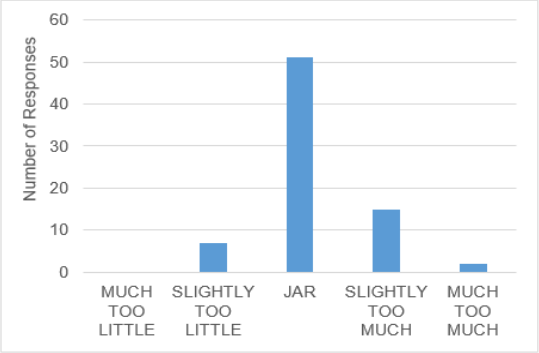

Figure 2B. JAR score for stickiness in blueberry powder confection

Stickiness JAR scores across both formulations showed that the majority of panelists felt the level of stickiness to be too high, and desired a decrease in stickiness in future formulations. This modification could be done in several ways, perhaps by adding a powdered coating to the outside of the confections or storing the confections at a more optimal temperature. Similar results were seen for firmness JAR scores in the extract formulation; however, those who did not rank firmness as JAR in the powder confection were divided as to whether the level was slightly too much or slightly too little. In this case, optimization would be more difficult and additional parameters would need to be considered before making any changes.

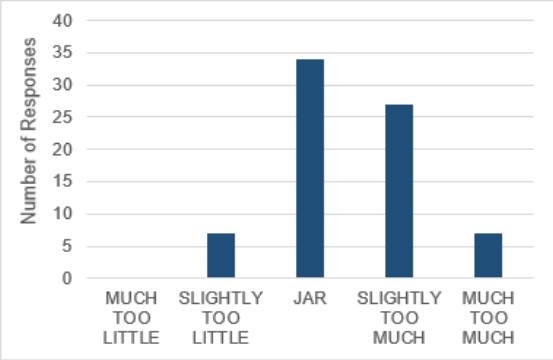

Figure 3A. JAR score for firmness in blueberry extract confection

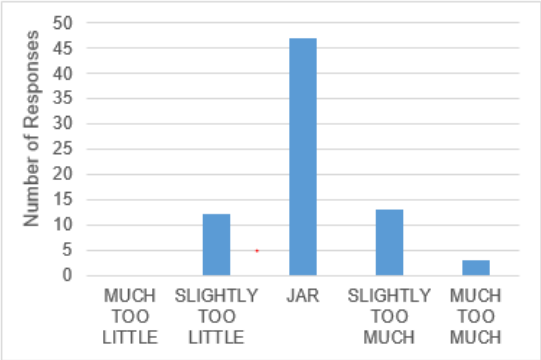

Figure 3B. JAR score for firmness in blueberry powder confection

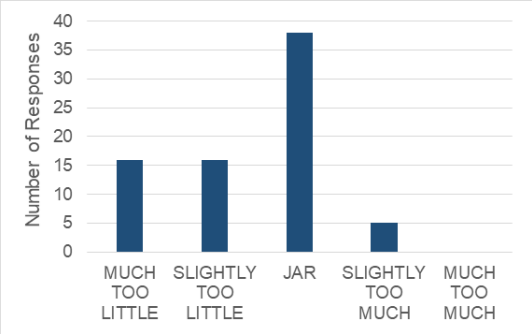

Figure 4A. JAR score for sour flavor in blueberry extract confection

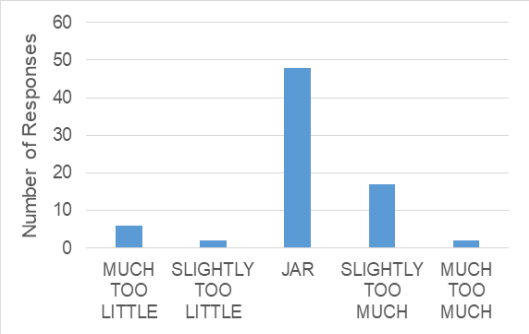

Figure 4B. JAR score for sour flavor in blueberry powder confection

Finally, sour flavor was assessed and it was determined that optimization was dependent upon the formulation chosen to use in future clinical trials. If clinical trials proceeded with the extract confection, panelists indicated they would prefer and increase in sour flavor, which could be achieved by the addition of more citric acid. Alternatively, if clinical trials proceeded with the powder confection, the majority of panelists desired a lower level of sour flavor, which could be achieved by decreasing the citric acid content. Overall, the same analysis could be continually employed across other attributes to improve the key sensory characteristics which have the greatest impact on consumer liking and sensory acceptability, and thus may affect compliance in a clinical setting.

Conclusion

In conclusion, results of the preference test showed no significant preference among the two blueberry confections, with 43 individuals preferring the whole blueberry powder confection and 32 individuals preferring the blueberry extract confection. No significant differences were seen among hedonic scores except in graininess ($p= 0.015$) and average overall liking scores of both confections fell in the "like slightly" category (powder= 6.33, extract= 6.21). Both the extract and powder confections assessed in this study were proven to be sensory acceptable for use in future clinical trials, but more work needs to be done comparing shelf stability and phytochemical uptake in humans.

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